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Growth Rate of the Seaweed *Kappaphycus alvarezii* and the Pacific White Shrimp *Litopeneaus vannamei* in Polyculture Intensive Ponds for Seed Seaweed Availability

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ABSTRACT

The culturing activity of *Kappaphycus alvarezii* is generally performed in coastal areas. This method has been used for many years and is still utilized. The number of seaweed farmers increases every year. This can lead to a conflict of interest among the farmers since seaweed needs a specific location for its growth. Hence, the best solution must be considered to avoid the potential conflict in coastal spatial utilization among farmers. One method that can be developed to sustain seaweed cultivation is to relocate the area from coastal to pond polyculture. In this context, this research aimed to study the performance of the *K. alvarezii* polyculture with the white leg shrimp *Litopennaeus vannamei* in intensive ponds. The research was done at the Culture Unit, Agriculture Polytechnic from Pangkep State, South Sulawesi Province, from June to August 2022. The quasi-experiment method was used. The pond size was 20x40 m. *K. alvarezii* was cultivated using the long line method. There were 10 lines with 120 points for each line, and the distance for each point was 25cm. At each point, around 100g of *K. alavarezii* was hanged. The stocking density was 15ind/ m^2 or 12.000 individuals per pond (PL-12). Rearing was done for 42 days for *K. alvareziii* and 60 days for *L. vannamei*. *L. vannamei* was fed three times a day, and detritivore bacteria were fed once a week. Special growth rate and water qualities were measured. The results showed that the specific growth rate of *K. alvarezii* ranged from 3.70- 3.75% per day, showing a good daily growth. The specific growth rate of *L. vannamei* ranged from 4.18- 4.38% per day. Water qualities during the research were in a range that still could be tolerant by *K alvarezii* and *L. vannamei*: with 30- 37ppm for salinity, nitrate 0.15- 2.14ppm for nitrate, 0.32- 0.51ppm for phosphate, and ranges of temperature from 30- 33°C, dissolved oxygen 5.79- 6.7ppm, and pH 6.9- 7.1. *K alvarezii* polyculture with *L. vannamei* showed a better specific growth rate than *K alvarezii* monoculture.

INTRODUCTION

Kappaphycus alvarezii is commonly cultured using the long line method or vertical line method at the sea shore **(Anggadiredja *et al*., 2006; Widowati *et al*., 2015; Nursidi *et al*., 2017)**, depending on the spatial availability in the water body.

Carrageenan contained in this species is the reason for its high economic value. If the farmers want to produce much carrageenan, they also need a wide cultivation area; they sometimes need to enlarge their cultural area. This puts high pressure on the ecosystem, which is susceptible to conflicting areas and leads to problems among fishermen and cultivators **(Nursidi *et al*., 2017; Rahadiati *et al*., 2017)**.

The *K. alvarezii* rise in size or biomass is influenced by diverse factors. Environmental aspects like water quality, weather conditions, currents, waves and also biological elements such as pests and diseases, alongside technical aspects like cultivation techniques, seaweed types, site choices, significantly impact seaweed growth and yield.

One of the difficulties experienced by seaweed farmers specially in Pangkep Regency coast that during the dry season, they will have difficulty obtaining quality seedlings. The monotonous planting pattern involves taking seedlings from the seaweed that will be harvested, causing many farmers to experience crop failures during the dry season. The decline in the seedling quality is due to the use of the offspring harvested from the seaweed of previous seasons.

One solution that can be done is to create a unique seedling garden for the *K. alvarezii* seaweed so that farmers will no longer have difficulty with the dry season. The issue that arises is that the location of the seedling garden cannot be obtained if it has to be located in the sea, which is already filled with residential areas for seaweed cultivation. If this seedling garden is also done at the sea, it will inevitably trigger conflicts with seaweed farmers regarding sea cultivation land.

Relocating the culture from the shore to the pond with intensive culture can be the solution. The pond is commonly used for culturing the seaweed *Gracillaria* sp., the white leg shrimp, the Nile tilapia, the milkfish, and some other biotas with economic value, using either a monoculture or polyculture system. There were several types of research about the *K. alvarezii* culture in the pond, monoculture, or polyculture, but there is still little related information.

Some research about *K. alvarezii* pond monoculture only shows information about the variation in specific growth rate, which is 0.96- 4.11% per day **(Athithan, 2014; Nursidi *et al*., 2017)** Additionally, research about *K. alvarezii* polyculture with the giant tiger prawns, the pacific white shrimp, and the red Nile tilapia with semi-intensive culture in the pond showed a specific growth rate of 4.15 and 3.35% **(Suharyanto & Mangampa, 2011)**. The specific growth rate for the *K. alvarezii* polyculture with the *Gracillaria verrucosa*, the white leg shrimp, and the milkfish is 3.8- 5.41% **(Yala *et al*., 2017)**. Based on these data, it is possible to culture *K. alvarezii* in the pond if the water quality is suitable.

Since the information about the *K. alvarezii* polyculture in the pond is still minor, it is essential to conduct more research. One biota that can polyculture with *K. alvarezii* is the Pacific white shrimp (*Litopenaeus vannamei*). The *L. vannamei* culture is growing with an intensive technology. However, there is not much information about it related to the *K. alvarezii* polyculture. Polyculture of these biota will give an economic and ecological advantage. Shrimp cultures are sources of nitrogen (N) and phosphate (P), especially from excess food, feces, and metabolism. These could affect the water quality, leading to slow growth.

The nutrients were absorbed to support its growth and to perform photosynthesis. The ecological function of *K. alvarezii* is to absorb the nutrients from its thallus to support its growth, perform photosynthesis, and produce oxygen. This is the mutual symbiosis between *L. vannamei* and *K. alvarezii*; water qualities are maintained since the nutrients are absorbed for *K. alvarezii* growth, which can lead to the optimum growth of *L. vannamei*. Additionally, the polyculture of *K. alvarezii* and *L. vannamei* could optimize the culture area because *L. vannamei* will be in the water column, and *K. alvarezii* will be on the surface. This research studied the performance of the *K. alvarezii* polyculture with *L. vannamei* in an intensive pond.

MATERIALS AND METHODS

The quasi-experiment method was used in this research, which is defined as an experiment with treatment, impact measurement, and an experiment unit. However, it does not use a random assignment to create a comparison in terms of summarizing the changes made by the treatment **(Campbell & Stanley, 2015)**. The research was conducted in the Culture Unit of Agriculture Polytechnic from Pangkep State, South Sulawesi Province, from June to August 2022. The research's outline is described below:

1. Preparations: This step included pond preparation, the *K. alvarezii* seed, the *L. vannamei* fry, and seed binding. There were two plots of pond, each sized 20 x 40m. The ponds were prepared by drying them for three days, liming as much as 300kg, filling the water with a 1.5m, 20ppm dosage of chlorine, and turning on the blower fan. After three days, fermentation made from bran, detritivore bacteria, yeast, and fish flour were stocked. After the plankton grew, ponds were ready for the *L. vannamei* fries. Additionally, a culture container for *K. alvarezii* was prepared, and ten lines included 120 points with a 25cm range for each line. *K. alvarezi* used about 100g for each point.
2. Stock: This step was done after the plankton growth. It showed a greenish watercolor. The stock was prepared in the afternoon. Fries were adapted to the new salinity. The density was 15ind/ m^2 or 12.000 individuals per pond (PL-12). The stocking of *K. alvarezii* using the longline method was done after the *L. vannamei* fries were three days old.
3. Maintenance: This step was conducted for 42 days for *K. alvareziii* and *L. vannamei*. Shrimp samples were fed 3 times a day; the detritivore bacteria were fed once a week, and seaweed was cleaned every two days. After 30 days, 10% of water was added to resolve the evaporation. *K. alvarezii* and *L. vannamei* were weekly weighed using the sampling method.

Fig. 1. Research unit in Pangkep Polytechnics

The variable measured in this research was the culture performance, including the specific growth rate, carrageenan level, and water qualities. The specific growth rate was counted based on the following formulation:

$$SGR = \frac{Ln\,Wt - Ln\,Wo}{t} \; x \; 100\%$$

Where, SGR = specific growth rate (%), Wt = final weight (g), Wo = initial weight (g), t = research period (days)

Water quality measurements in this study used instruments which can be seen in Table (1). The result from the specific growth rate and water quality data were analyzed using a descriptive analysis.

Table 1. Water quality parameters and its instruments

Water quality parameter	**Instrument**
Salinity	Hand refractometer
Temperature	Digital thermometer
pH	pH meter
Dissolved oxygen (DO)	DO meter
Nitrate	Spectrophotometer
Phosphate	Spectrophotometer

RESULTS

1. Specific growth rate

The simultaneous growth of the cultured organisms is one biological aspect that became the objective of the polyculture system. The mean of the specific growth rates of *K. alvarezii* and *L. vannamei* cultured using a polyculture system during 28 days was relatively unchanged (Figs. 2, 3). The specific growth rate of *K. alvarezii* was 3.70-3.74% per day. This shows that the daily growth rate was excellent and suitable for seed preparation. The daily growth rate for *K. alvarezii* was not less than 3%, which is considered an advantage **(Anggadiredja *et al.*, 2006)**. In addition, the specific growth rate for *L. vannamei* showed no significant variance in the 4.18- 4.31% per day.

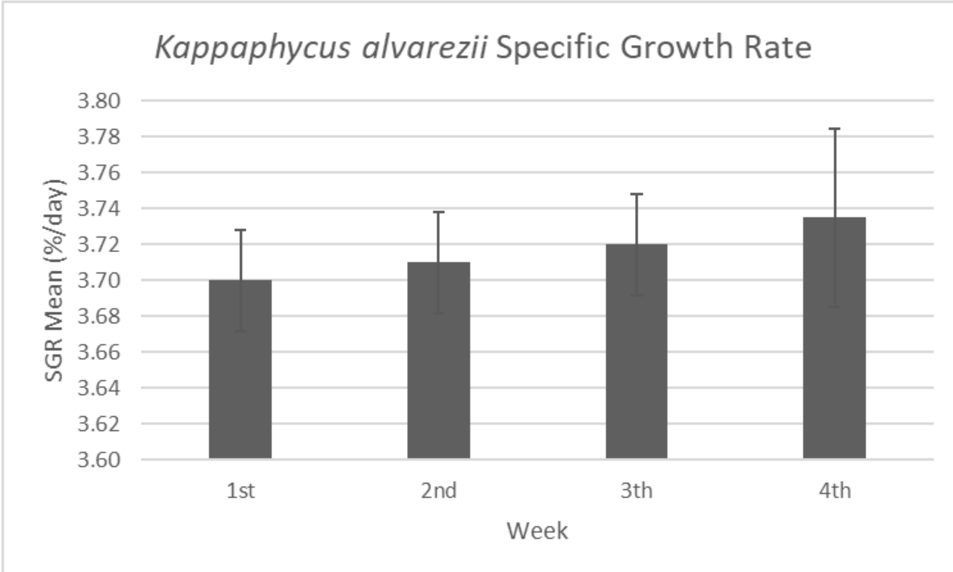

Fig. 2. The specific growth rate of *Kappaphycus alvarezii*

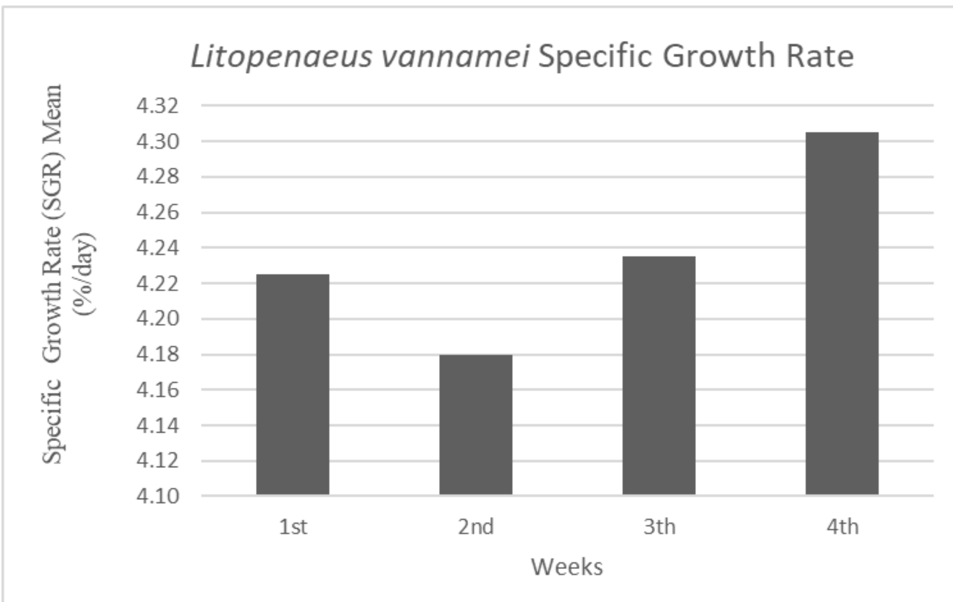

Fig. 3. The specific growth rate of the Pacific white shrimp (*Litopenaeus vannamei*)

2. Water quality

The results of the water quality in the pond research unit during the experiment are depicted in Table (2).

Table 2. Water quality measurement in the pond

Measurement	Result	Standard	Source
Salinity (ppt)	32-37	15 – 30	**(Reis *et al*., 2011)**
Nitrate (ppm)	0.15 – 2.14	1 - 3	**(Athithan, 2014a)**
Phosphate (ppm)	0.32 – 0.51	0.01 – 0.02	**(Mangampa, 2014)**
Temperature (ºC)	30 - 33	26 - 33	**(Prema, 2013)**
Dissolved oxygen (ppm)	5.79 – 6.7	5.6 – 6.4	**(Cokrowati *et al*., 2018)**
pH	6.9 – 7.1	7.00 – 8.50	**(Parakkasi *et al*., 2020)**

DISCUSSION

The specific growth rate value obtained in this research was relatively high. It was caused by a good environment supporting the growth of *K. alvarezii* and *L. vannamei*. Alga growth rate is highly dependent on light intensity, temperature, salinity, dissolved nutrients (nitrate and phosphate), and respiration level **(Singh & Singh, 2015)**. In this research, *K. alvarezii* was located in 30cm depth, which makes light intensity more optimal. The ideal depth for seaweed is 30- 50cm from the water surface **(Fadilah *et al*., 2016)**. Light is a physical factor that is important for the photosynthesis process of the seaweed and is used to absorb nutrients like nitrogen (N), carbon (C), and phosphorus (P) into cells. Additionally, if photosynthesis activities are disturbed, the production of the dissolved oxygen and a-chlorophyll as water fertility indicators will be decreased **(Yang *et al*., 2015; Yala *et al*., 2017)**.

The synergy between *K. alvarezii* and *L. vannamei* in creating optimal conditions for both biotas also affects the high specific growth rate. Food given to *L. vannamei* is left uneaten and thus left in the water column. Some of the food that is consumed cannot be digested by *L. vannamei*. Food digested is converted into energy for metabolism and growth. Meanwhile, the undigested food is thrown away in feces. Leftover food, feces, and the left metabolism activities are nutrient waste that could affect the water quality if it accumulates in large amounts and does not decompose. In this research, the nutrient wastes were decomposed by decomposer bacteria, resulting in inorganic particles that *K. alvarezii* can adsorb.

In intensive or semi-intensive cultures, such as fish or shrimp, only 23- 31% of the nitrogen and 10- 13% of the phosphorus from the given food is assimilated. Meanwhile, 14- 53% of the nitrogen and 39- 67% of the phosphorus remained in the water column or the sediments **(Schuenhoff *et al*., 2003)**. Both nutrients are common waste from culture activities in the form of dissolved particles. Seaweed provides essential ecosystem services, such as oxygenation and dissolved nutrients (N, P, and K) for growth. It also can be used as an extractive component to eliminate inorganic nutrients and mitigate harmful environmental impact potentially **(Corey *et al*., 2014; Kim *et al*., 2014; Rose *et al*., 2015; Wu *et al*., 2017)**. The role of seaweed has reasonable implications for the water quality so that *L. vannamei* can use all water columns. Supported by feed availability, the growth of *L. vannamei* gave a good response.

The results for the specific growth rate of the *K. alvarezii* polyculture with *L. vannamei* (3.70- 3.74% per day) in this research are higher compared to the specific growth rate of *K. alvarezii* cultured with a monoculture system (3.36- 3.40% per day) **(Nursidi *et al*., 2017)**. It is also higher than that previously reported on seawater, with a seaweed specific growth rate of 1.11± 0.27% per day and a shrimp specific growth rate of 2.36± 0.76% per year **(Lombardi *et al*., 2006)**. Nutrient availability sourced from the leftover food, faeces, and metabolism activities from *L. vannamei* caused the growth of *K. alvarezii* to be higher in the polyculture system.

The specific growth rate value in this research is also higher compared to other polyculture research with a zero water exchange system done, in which the specific growth rate of Gr*acilaria corticata* and *L. vannamei* was only 0.31- 1.23% and 1.70- 1.97% per day **(Fourooghifard *et al*., 2018)**. Conversely, the growth rate of *K. alvarezii* in this research is lower than that previously recorded for *K. alvarezii*, with a value of 3.8- 5.41% per day **(Yala *et al*., 2017)**. In addition, these assimilation rates were lower compared to the values reported in the study of **Suharyanto and Mangampa (2011)**, where the specific growth rate of *K. alvarezii* ranged from 3.35 to 4.15% per day in the polyculture of the tiger shrimp (*Penaeus monodon*), *L. vannamei*, and the red Nile tilapia under semi-intensive conditions. In this research, *K. alvarezii* was polycultured with *Gracillaria verrucosa*, *L. vannamei*, and the milkfish in the pond.

The lower value of the specific growth rate, compared to some previous research, is assumed to be attributed to water salinity. The research was organized during the dry season when the salinity was high. It is common in Indonesia that the seaweed growth slows during the wet season caused by fluctuating salinity levels **(Rahadiati *et al.*, 2017b)**. One research describes that the *K. alvarezii* culture on the shore shows better growth during the rainy season compared to the dry season **(Nursidi, *et al*., 2017)**. This is because no water flow brings nutrients and minerals. Seaweed will grow slower if the salinity is too low (< 15ppt) or too high (> 35ppt) since it could affect the biochemical and physiological mechanisms. On the other hand, the osmosis pressure is related to cell membranes during nutrient transport; it disturbs the function of enzymes, inhibits cell division, and hinders the absorption of nutrients becoming non optimal **(Hurtado & Biter, 2007; Choi *et al*., 2010)**.

Water quality parameter is a production factor determining the successful intensive polyculture system. Salinity is a limiting factor for the *K. alvarezii* culture and could affect both the growth and carrageenan yield. The optimum salinity for *K. alvarezii* is reported to be around 35ppt (parts per thousand), as noted by **Reis *et al.* (2011)**. However, *K. alvarezii* could also grow within the range of 30- 37ppm, and it has been observed to tolerate high salinity levels as well **(Yala & Sulistiawati, 2017)**.

Other water parameters that still could be tolerated by *K alvarezii* and *L. vannamei* are nitrate at 0.15- 2.14ppm, phosphate at 032- 0.51ppm, temperature at 30- 33°C, dissolved oxygen at 5.79- 6.7ppm, and pH at 6.9- 7.1. Among all parameters that were measured, both nitrate and phosphate were higher than the standard levels.

In several studies on the *K. alvarezii* culture in ponds, phosphate values surpassed the standard levels. Despite this, the seaweed growth rates ranged from 0.30 to 3.10% per day **(Lombardi *et al.*, 2006; Athithan, 2014; Yala & Sulistiawati, 2017; Irawan *et al.*, 2024)**. This suggests that *K. alvarezii* can be successfully cultivated as seedlings in ponds but may not be sustainable for a long-term growth under these conditions.

CONCLUSION

The *K. alvarezii* polyculture with *L. vanname* results in a higher specific growth rate than *K. alvarezii* monoculture. The *K. alvarezii* growth in pond means that a pond can be used as a seedling place or storage medium before *K. alvarezii* is brought to the sea for cultivation. Further research on higher stocking density of *L. vanname* and an additonal biota such as the milkfish is suggested.

REFERENCES

Anggadiredja, J.; Zatnika, A.; Purwoto, H. and Istini, S. (2006). Seaweed, Penebar Swadaya. Indonesia. (In Indonesian)

Athithan, S. (2014). Growth performance of a seaweed, Kappaphycus alvarezii under lined earthen pond condition in Tharuvaikulam of Thoothukudi coast, South East of India. Res J Anim Vet Fish Sci, 2: 6–10.

Campbell, D. T. and Stanley, J. C. (2015). Experimental and quasi-experimental designs for research. Houghton Mifflin Company, Boston, 88pp.

Choi, T.; Kang, E.-J.; Kim, J. and Kim, K.-Y. (2010). Effect of salinity on growth and nutrient uptake of Ulva pertusa (Chlorophyta) from an eelgrass bed. Algae, 25(1), 17–26.

Cokrowati, N.; Arjuni, A. and Rusman, R. (2018). Growth of *Kappaphycus alvarezii* From Culture Tissue. Jurnal Biologi Tropis, 18(2), 216–223. https://doi.org/10.29303/jbt.v18i2.740 (In Indonesia)

Corey, P.; Kim, J.; K., Duston, J. and Garbary, D. J. (2014). Growth and nutrient uptake by Palmaria palmata integrated with Atlantic halibut in a land-based aquaculture system. Algae, 29(1), 35–45.

Fadilah, S.; Alimuddin.; Pong-Masak, P. R.; Santoso, J. and Parenrengi, A. (2016). Growth, Morphology and Growth Related Hormone Level in Kappaphycus alvarezii Produced by Mass Selection in Gorontalo Waters, Indonesia. HAYATI Journal of Biosciences, 23(1), 29–34. https://doi.org/10.1016/j.hjb.2015.09.004

Fourooghifard, H.; Matinfar, A.; Mortazavi, M. S.; Ghadikolaee, K. R. and Mirbakhsh, M. (2018). Nitrogen and phosphorous budgets for integrated culture of whiteleg shrimp Litopenaeus vannamei with red seaweed Gracilaria corticata in zero water exchange system. Iranian Journal of Fisheries Science. 17. https://doi.org/10.22092/ijfs.2018.116382

Hurtado, A. and Biter, A. (2007). Plantlet regeneration of Kappaphycus alvarezii var. Adik-adik by tissue culture. Journal of Applied Phycology, 19, 783–786.

Irawan, H.; Permatasari, M. N. and Attaqi, A. N. (2024). Different Kind of Seaweed as Fitoremediation Agent in Semi-Intensive Asian Tiger Shrimp (*Penaeus monodon*) Semi Intensif. Journal of Marine and Aquatic Sciences, 9(2), 311. https://doi.org/10.24843/jmas.2023.v09.i02.p16 (in Indonesian)

Kim, J. K.; Kraemer, G. P. and Yarish, C. (2014). Field scale evaluation of seaweed aquaculture as a nutrient bioextraction strategy in Long Island Sound and the Bronx River Estuary. Aquaculture, 433, 148–156.

Lombardi, J. V.; De Almeida Marques, H. L.; Pereira, R. T. L.; Barreto, O. J. S. and De Paula, E. J. (2006). Cage polyculture of the Pacific white shrimp Litopenaeus vannamei and the Philippines seaweed Kappaphycus alvarezii. Aquaculture, 258(1–4), 412–415. https://doi.org/10.1016/j.aquaculture.2006.04.022

Mangampa, M. (2014). Polyculture Asian Tiger Shrimp (Penaeus monodon), Milk Fish (Chanos chanos), Nile Tilapia (Oreochromis aureus x O. niloticus), and Seaweed (Gracilaria verrucosa) di Acid Sulphate Soil Pond. Prosiding Forum Inovasi Teknologi Akuakultur, Pusat Penelitian dan Pengembangan Perikanan Budidaya, , Kementerian Kelautan dan Perikanan, 1-12. (in Indonesian)

Nursidi, N.; Ali, S. A.; Anshary, H. and Tahya, A. M. (2017). Environmental Parameters and Specific Growth of Kappaphycus alvarezii in Saugi Island, South Sulawesi Province, Indonesia. AACL Bioflux. 10(4). 698-702

Nursidi, N.; Mauli, M. and Heriansah, H. (2017). Development of seaweed Kappaphycus alvarezii cultivation through vertical method in the water of small islands in South Sulawesi, Indonesia. AACL Bioflux. 10(6). 1428-1435.

Parakkasi, P., Rani, C., Syam, R. and Achmad, M. (2020). Growth response and quality of seaweed Kappaphycus alvarezii cultivated in various coastal ecosystems in the waters of West Sulawesi, Indonesia. AACL Bioflux. 13(2) : 627-639.

Prema, D. (2013). Site selection and water quality in mariculture. Central Marine Fisheries Research Institute. Kerala, India : 35-43.

Rahadiati, A.; Soewardi, K. and Wardiatno, Y. (2017). Spatial pattern and temporal variation of water quality and carrying capacity for seaweed mariculture in Takalar, Indonesia. AACL Bioflux, 10(4), 894–910.

Reis, R. P.; Loureiro, R. R. and Mesquita, F. S. (2011). Does salinity affect growth and carrageenan yield of Kappaphycus alvarezii (Gigartinales/Rhodophyta)?: Does salinity affect Kappaphycus alvarezii? Aquaculture Research, 42(8), 1231–1234. https://doi.org/10.1111/j.1365-2109.2010.02699.x

Rose, J. M.; Bricker, S. B.; Deonarine, S.; Ferreira, J.; Getchis, T.; Grant, J.; Kim, J.; Krumholz, J.; Kraemer, G. and Stephenson, K. (2015). Nutrient bioextraction. Encyclopedia of Sustainability Science and Technology, 10, 1-33, DOI 10.1007/978-1-4939-2493-6_944-1.

S**chuenhoff, A.; Shpigel, M., Lupatsch, I.; Ashkenazi, A.; Msuya, F. E. and Neori, A**. (2003). A semi-recirculating, integrated system for the culture of fish and seaweed. Aquaculture, 221(1–4), 167–181.

Singh, S. P. and Singh, P. (2015). Effect of temperature and light on the growth of algae species: A review. Renewable and Sustainable Energy Reviews, 50, 431–444.

Suharyanto, S. and Mangampa, M. (2011). Multitropik aquaculture asian tiger shrimp (Penaeus monodon), red nile tilapia (Oreochromis niloticus) and seaweed in pond. Prosiding Forum Inovasi Teknologi Akuakultur, 235–242. (in Indonesian)

Widowati, L. L.; Rejeki, S.; Yuniarti, T. and Ariyati, R. W. (2015). Production efficiency of E. cotonii seaweed using the vertical long line cultivation method as an alternative use of the water column. Saintek Perikanan. 11(1). 1858-1864. https://doi.org/10.14710/ijfst.11.1.47-56 (in Indonesian)

Wu, H.; Kim, J. K.; Huo, Y.; Zhang, J. and He, P. (2017). Nutrient Removal Ability of Seaweeds on Pyropia yezoensis Aquaculture Rafts in China's radial sandbanks. Aquatic Botany, 137, 72–79.

Yala, Z. R.; Sulistiawati, D.; Masyahoro, M. and Nasmia, N. (2017). Seaweed (Eucheuma cottonii) Growth in Polyculture Application. AACL Bioflux, 10(5), 1064–1073.

Yang, Y.; Chai, Z.; Wang, Q.; Chen, W.; He, Z. and Jiang, S. (2015). Cultivation of seaweed Gracilaria in Chinese coastal waters and its contribution to environmental improvements. Algal Research, 9, 236–244.